BE 514 Project 2 Therapeutic or Assistive Social Robot Design

Social Robot Mr.Orange for Elder man with Traumatic Brain Injury

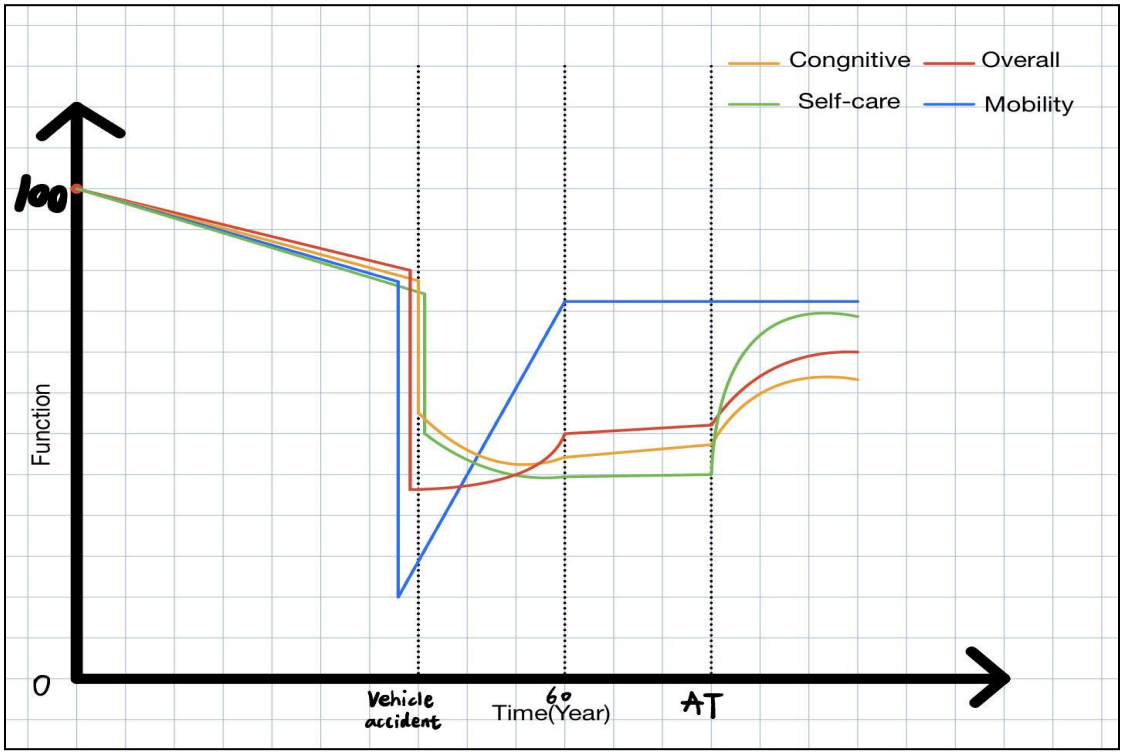
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1. Patient Needs and assumption

Our patient is a 60-year-old Indian man who sustained a sequelae head-injury from a motor vehicle accident in Los, California. He shows many of the symptoms associated with frontal lobe injury, impairment in executive function. In medical terms, the frontal lobe is responsible for higher cognitive functions such as memory, emotion, impulse control, problem solving, social interaction, and motor function. Damage to the neurons or tissue of the frontal lobe can lead to personality changes, difficulty concentrating or planning, and impulsivity. As a result, the patient often easily gets lost when involved in specific tasks like fully dressing himself up in the morning and adding ingredients during cooking. Luckily, the patient currently lives at home with his wife, who is his major caregiver, and he has long-term disability insurance. To help with his disability, his family required us to design and prototype a robot companion that will support him with daily activities mentioned above and thus improve his overall living quality.

Since our patient loves yardworks, we assumed this yard is mixed with stone ground, garden and swimming pool but has flat road surface. As for social networking, we assumed he might have some friends visit him once a while and Indian community or religious activities. The climate of Los Angeles is mid to hot year-round, and mostly dry. Because of this, we don’t need to consider using some waterproof materials for the robot. We also assumed that his family members are also part of his rehabilitation process such as accompanying him for grocery shopping to make sure everything is well prepared. Since he is already 60 years old, there might be other potential mental degeneration and fragileness as well as reduction in hearing, vision and lagging in response. So when designing the social robot interaction with the patient, those aspects need to be taken into consideration as well.

2. Disability Curve



The disability curve for our patient can be divided into three phases: (1) Phase 1 right after the vehicle accident, (2) Phase 2 while he gradually recovered from the accident and getting older up to 60 years old and (3) Phase 3 after he will apply assistive technologies. Right after the accident, his overall functions dropped immediately. Especially his mobility, which dropped the most among all functions, but also it is the one recovered the fastest. The cognitive and self-care functions are also recovered but at a pretty slow pace. We expect that after our assistive technology is applied, the patient's cognitive and self-care ability will increase by at least 40%.

3. HAAT model for the elder man with traumatic brain injury

Human	Activity	Context	AT
60-years-old male - Elder - Healthy physical condition now - Physical condition will go down as he ages **Indian living in Los Angeles** - Indian culture/preferences - Large, urban city - High cost of living **Frontal Lobe Injury** - Head-injury from motor vehicle accident - Cognitive disability - Impairment in executive function - Temporal memory loss - Forgets to do ADLs such as getting dressed/shave **Adult with Disability Insurance** - Does not need to work - Stays in the house - Wants to do housework/yard work - Decent financial condition **Lives with His Wife** - Wife is out of the house during the day - Little interaction with people other than his wife	**General** - Self-care, ADLs: getting completely dressed - Puttering around the house **Work and productive activities** - Yardworks: watering flower, seeding, vegetable picking - Cooking: baking, turning on/off the oven, adding ingredients **Clinical** - Health check, visit clinicians **Leisure** - Family activities: watching TV, playing with grandchildren - Social connection: phone call with friends	**General** - Home - Around house - Restaurants - Stairs **Social** - Immediate social environment: Friends visiting, interaction with his family members. **Cultural** - Indian community **Physical** - Los Angeles, California - Persistent sunshine, Mediterranean climate, - Yard environment.	**Function** - Easy use for elders, large fonts, signs, voice assistant - Alert battery life - Companion, conversations - Automatic following the user - Smart home, control house appliance, automatic door lock, oven and stove turn-off - Fall and emergency detection and timely warning to caregiver - Regular ADL reminders - Monitor progress of on-going tasks, remind regularly and ensure completion - Easy contact with relatives and friends, video call - Brain exercises, games - Leisure and entertainment **Cooking & Yarding** - Written-in and record recipes, especially Indian dishes - Video recipes and instructions - Keep record of current food stock and indicate recipe availability - Monitor cooking progress and remind next steps - Yarding and housework knowledge

4. State of the Art and Design Opportunities

Currently, a number of social robots have been put forward to the public whose features are summarized in **Table 1** according to the AT requirements analyzed above[1].

ElliQ that was put forward in January 2017 is a social robot developed specifically for elders, and was awarded a prestigious Innovation Award in the Smart Home category in January 2018. The price is $1,499 in 2019. The main functions include companionship, assistance, motivation and happiness. Specifically, it can do small talks and daily conversations with no need to remember commands; for assistance it can help with events and medication reminders, searching and booking issues, and family and friends notification and connection such as video calls; for enjoyment, it can provide news, weather, sports, music, jokes, trivia, games, and more fun activities; it may also motivate healthier habits through goal settings and mind exercises.

The iPal Robot from AvatarMind, was introduced in China. It is a tall mobile social robot with a humanoid form. The consumer edition is priced at $3,499. Custom partner versions are listed as being from $3,899 to $5,499. Although initially designed for young children, the company is listing Senior Companionship/Care first among the target uses. Specifically, it will offer a constant companion that supplements personal care services and provides security with alerts for many medical emergencies such as falling down.

Buddy from Blue Frog Robotics is intended to serve the whole family, but the company does emphasize the benefits it offers for the elderly and their families. It has a hybrid humanoid (“arms” are an option) physical form. It protects the home, offers assistance in the kitchen, entertains the family with music and videos, acts as a calendar and alarm clock, and interfaces with popular smart home solutions. Buddy is 56cm tall and weighs 5kg. Its brain is an integrated android tablet and is able to hear and speak thanks to built-in speakers and a microphone array system. It is fully mobile, with three wheels, and is equipped with a variety of sensors to deliver various functionalities. These sensors include a 3D camera, ultrasound, infra-red and thermal sensors, a range-finder sen-sor, and ground detectors. The sensors, coupled with Buddy’s mobility, mean that he can trav- el autonomously and learn and interact with the world around him. The crowdsource price was $699 to $999.

Jibo is a stationary social robot in a non-humanoid form, it can do conversations, and may offer great companionship, but the executive functions are not as promising. The price was $899 when released to the public.

Temi is a robot currently available for sale. It is a tall mobile robot with a non-humanoid form. While it is not being developed as “social” it includes conversational assistance via Alexa or its own technology. It is just like “Alexa on wheels”, providing much of the same functionality plus its ability to recognize and follow users around. Telepresence is its primary focus, it also has a tray to carry things placed there. Other functions include smart home, security and safety, and entertainment. Sales began October 1, 2018, and were priced at $1,999 until May 15, 2020 when the price was increased to $3,999. Other similar products include Cutii, Ohmni, Care-O-bot, Zenbo, Furo-i, Pepper, Kuri, and so forth.

It can be observed from **Table 1** that while most social robots have general functions such as conversation, company, and reminders. Most of them lack specialty in recipe and kitchen assistance. Also, their prices range from $1,000 to $4,000, which are relatively expensive. Hence, **recipe functions**, and **lower costs** are two main potential design opportunities. We also believe it is necessary to **adapt existing functions in a way that fits better to his poor memory**. These functional requirements are then prioritized based on the state of the art and design opportunities. An importance-satisfaction analysis was done and the requirements (**Fig.1**). High importance but low satisfaction were assigned high design priority whereas important functions with high satisfaction were considered must-to-have but with lower design priority. Specifically, it was decided that the **top priority functions** are a **recipe** - as there lacks relevant functions, **mobility** - as the user would work around the yard and the mobility there needs improvement, **smart home** - improve by taking the memory deficient problem into consideration, and **costs**. Other requirements should be provided but would need less design improvement. The assigned priorities can be seen at **Table 1**.

5. Design Process

a. Concept Generation

Stepping from the design opportunities, we brainstormed a number of intermediate ideas (see **Appendix III**). Main motivations behind include his interests in cooking, yarding, and his needs to keep track of activities. Features of the six ideas were combined or excluded based on actual feasibility, prototype feasibility, or through majority voting.

b. Concept Selection

We decided that the optimal solution to the patient's problem would be a robot companion with reminder, voice assistance, kitchen assistance and autonomous and uneven-terrain mobility. A

stationary robot is likely to perform weakly in the garden and backyard scenario and is hardly different from existing devices like Alexa. The solutions (c) and (e) are discarded as they require too much extra effort in moving or labeling items. Some other considerations behind concept selection are described below. The judgment was made based on the design tension and the universal principles of design we have discussed[4].

i. Stability vs Flexibility

While stability is a key factor to be considered with the patient's requirement, flexibility is also inevitable. For uneven-terrain mobility, both caterpillar track and rubber wheels are considered for the initial design of the robot. Caterpillar track provides more traction, less ground disturbance. Wheeled machines excel in applications where the ground conditions are firm and higher travel speed is required. Wheeled machines weigh less than track units, and thus are portable and easy to maintain, providing greater flexibility[2]. We prefer flexibility since we want to incorporate the flexibility in use principle. The robot ought to be used not only in the patients' context, but also other patients that have similar neural problems.

ii. Power efficiency vs best performance

Another concept is the balance between power efficiency and the best performance of the tasks that the robot can do. Usually modules with better performance come with a greater energy expenditure. Since the robot ought to be powered by mobile power sources like batteries, we cannot ignore the importance of the standby time of the robot. For example, the caterpillar track will typically require a motor with larger power compared to the wheels due to its heavier undercarriage and increased stability. Also, in terms of motors, DC motors generally have a larger power and come with greater energy consumption per unit time compared to servo motors. Moreover, when considering the choice between an LCD display and touch screen module for user interaction, although touch screen brings a better user experience, it costs more power compared to the ICD module.

iii. Power vs controllability

Despite the power of the robot is crucial to the speed that it can move, controllability is also a concept that should not be overlooked. As stated above, DC motors generally have a larger power and its speed solely depends on the voltage across the motor. Although H-bridge can help resolve the direction of DC motors' direction, the controllability of DC motors is still limited.

Comparatively, servo motors are slightly less powerful but allow speed control by Arduino IDE algorithms. We chose power efficiency over the best performance, but controllability over power. This is because we want to minimize the effort that the user makes to replace the battery of the robot, which follows the low physical effort principle.

iv. Individual vs entirety

Another important concept is to consider the compatibility of selected design's performance individually vs as a entirety. For example, in order to account for the autonomous motion and response to front barriers, distance sensors are needed for the initial design. Both the ultrasonic sensor and the IR sensor work great as individual modules. They both work well in places that are dim and super compatible with a microcontroller. The IR distance sensor has a larger detection range and has a faster refresh rate, making it suitable for detection of fast-moving targets. However, the IR light reflected from the measured object may interfere with other components in the robot[3], causing problems in the design as a whole. The concept dilemma is also shown in the design of heat sensing functionality, in which the thermostat is more functionally complete as an individual product compared to thermistor, but is incompatible with other parts of the robot. Therefore, the balance between individual functionality and that of the assembly is to be considered. We chose entirety, not only because of the overall compatibility, but also for the convenience of the user. The robot ought to be functioning as a entirety without having components interfering with each other and thus leads to errors. We do not wish that the tolerance for error of the robot is low, so that users have to look for technicians for maintenance of the robot.

v. Practicality vs aesthetic appealing

Due to limited time and material for prototype design, a balance between practicality of the design and its appearance ought to be considered. We have some fantastic ideas for the appearance of the robot: either be like a little dog/ cat that looks like an animal companion or a cute typical robot-like appearance. However, the robot also needs to be feasible to prototype in practical terms, whether the designed appearance can allow the expected functional modules to be well-installed and worked is also a crucial factor to think about in the brainstorming phase. Here we weighed practicality over aesthetic appeal. As the design tension #2 says, the key point of the design is to address an unmet medical need, and we hope our design will follow this major principle.

6. Final Solution

The final design solution is named Mr. Orange with an orange-colored outlook, based on the subject's potential interests in nature, animals and vegetables (**Fig.2**). The warm color also looks friendly and enthusiastic. It consists of an orange-like head part with the eyes being ultrasonic sensors, a body part containing electronic parts and two arms extending from the body meant for holding a screen or plate-like items. A set of easily pluggable decorative components such as animal ears, vegetable leaves, and chef hat are also provided so that the user may customize the robot's appearance according to his will.

Mr. Orange may perform 6 behaviors, including movement, voice control and conversations, reminder, smart recipe, heat sensing and warning, and battery alert, which is elaborated in the following bullet points:

- **Movement (Remote control & Autonomous):** Mr. Orange can self-navigate and move freely in both the room and the yard, avoiding potential barriers in front of it. It can also be remotely controlled similar to a TV remote control, in which users give commands like turning on/off, going forward/backward, turning left/right to the robot.
- **Heat sensing:** Mr. Orange can detect rising temperatures in the surrounding environment. An alarm audio message will be reported after the temperature is higher than a specific threshold.
- **Battery alert:** Mr. Orange can continuously observe battery levels that power itself. An alarm audio message that reminds the user to replace the battery will be reported if the voltage of the battery is lower than a specific threshold (7V). In addition, a battery icon will be displayed on the screen for more intuitive indication of remaining charge.
- **Voice control and conversations:** Mr. Orange may have natural conversations with the user and play as a voice assistant similar to Siri or Alexa. Specifically, it can tell jokes, play music, search for information, and execute commands such as turn of the lights.
- **Reminder:** Mr. Orange may keep a list of next-to-do tasks and regular routines such as checking for proper dressing every morning, doing chores every week, and so forth. It may then send the reminder message at a fixed time or when being asked. The tasks can either be set by himself or his wife and family members on the robot, on software, or its control website.
- **Smart recipe:** Mr. Orange maintains a rich recipe database that contains highly detailed information, including ingredients and cooking appliances required, step-by-step

instructions with figures, servings, calories and nutrients. This can be set by the user from his experience, pulled from existing recipe databases, or obtained online. Ideally, each recipe can be paired with a video-version tutorial. It also has a full record of cooking appliances, available ingredients and current food stock, with due date and locations. This information can be set up by his wife. Mr. Orange supports smart meal plans that automatically check for availability of required resources when a recipe is planned. The unavailable items could be added to the shopping list and sent to his wife. It can also recommend recipes based on nutritional information or how close the foods are to the due date. Once planned, the recipe would interact with the user to track the progress to avoid sudden loss of the user. It will send instructions of one step at a time and requires a voice/touch command indicating completion of the current step to proceed to the next. It contains the location information of any resource required to avoid difficulties in finding. For time-sensitive steps, it may automatically set-up a timer and send a reminder once the time is up so that the user would not forget about the ongoing cooking.

a. Prototype Implementation

We prototyped the design using mainly Arduino (**Fig.3**). All-orientation motion of the robot is realized through two continuous servo motors on which rubber wheels are attached. The autonomous navigation is achieved through ultrasonic sensors that measure distance to barriers in front of the robot and rotate through a servo motor it is fixed to. The behavior can be further controlled remotely using an Elegoo IR board and sensor. A thermistor is used to realize heat sensing with a 35 Celcius threshold set for function validation. Battery sensing is achieved through a voltage dividing circuit. Voice assistant is realized through an open-source package HeyAthena works in the Python environment on PC and is further connected to Arduino through bluetooth (Fig.3a). It is hoped that the audio response can be directly transmitted to the Arduino. However, due to the memory limitation of Arduino board, limited speech packages available in Arduino, and the large audio message versus limited bluetooth transmission speed, a compromised solution is adopted that the audio message generated by HeyAthena is stored, converted to numeric codes and pre-stored as an Arduino library. The voice message received by HeyAthena would be sent in text through bluetooth and trigger a programmed audio response at Arduino (Fig.3b). The reminder and recipe function are realized through two open-source APIs Grocy, and Spoonacular (Fig.3c). The outer shell is made through 3D printing, laser cutting and spray painting (Fig.3d). Parts list see **Table 2**.

b. Prototype Performance

Most of Mr. Orange's functions perform close to our expectation. For movement functions, after several trials of testing and calibration, Mr. Orange can correctly execute the commands as programmed in Arduino IDE algorithms— the servo as the robot head can turn 180 degrees and the continuous servo motors can rotate in the correct directions as the IR control "tells" it to do. When the robot is connected to a PC with USB wire, the UNO board embedded inside the robot correctly and continuously outputs the surrounding temperature and remaining battery level, validating that the thermistor and battery life modules work as expected. Also, the 3D printed support and laser-cutted casing fits electrical components pretty well, which ensures the well-functioning of other modules. In the case of the voice control function, the bluetooth module is able to receive signals input from voice assistants on a PC, which allows the robot to respond to some daily greetings.

Nevertheless, due to limited time and hardware/software resources, some of the functions are unable to perform as our expectations. For example, due to the memory limit of the arduino board, the functions of smart recipe and reminder have to be executed separately with two sets of entirely different algorithms, which makes concurrent actuation of these two functions difficult. As the bluetooth transmission can not accommodate the large audio files, the audio responses are pre-recorded and programmed, and may not realize flexible, natural interactions. Moreover, since we are unable to acquire a speaker with enough volume output, the sound of alarming messages and voice assistant responses are relatively low, which can only be heard in quiet rooms.

7. Storyboard and Demo

Mr. Orange can interact with the user just as a friendly companion and a professional assistant (**Fig.4**).

7.1 Voice assistant

The user can simply activate interaction through calling its name Mr.Orange, and say the command. When our subject encounters Mr. Orange, he just greets like meeting one of his friends, "Hey, How's it going?"

Mr. Orange then replied, "I'm doing well. How about you?"

Sometimes the user feels lonely staying in the house all day. He saw Mr.Orange and said, "Hey, Mr.Orange, tell me a joke."

Mr.Orange answered, “A termite walks into the bar and asks, Is the bar tender here?” He can also control home appliances using voice commands like “turn on the light”. Ideally, the message will also be shown on the robot screen.

Demo: See Fig.4a, video link, link2, link3.

7.2 Reminder

As the user gets up in the early morning, Mr.Orange will say something like “Morning! Today is shave day! Stop by the mirror to see how you look today!” Just to let the user check if he has properly dressed and shaved. When he suddenly gets lost, he may ask “what should I do next” or “what am I doing”, and Mr.Orange would let him know what are the current or next tasks by responding something like “You’re cooking cookies! There are 8 minutes left”, or “You should pick some carrots at the yard next!”

Demo: See Fig.4b, video link.

7.3 Smart Recipe

At night, the user makes some meal plans for the weekends. He wants to make some fast foods to welcome his grandchildren and adds pizza, fried chicken and chocolate cookies. He hasn't cooked fried chicken before and hence he said “search recipe for fried chicken” first. He will be able to review the contents and select for an ideal one (Not shown in demo due to lack of touch screen). When he tried to add pizza, Mr.Orange reminds “You have three products missing for recipe pizza, which are salami, tomatoes, cheese.” He then adds these items to the shopping list and sends them to his wife. When his wife returns from shopping the other day, she can easily add the item to the food stock through scanning the product barcode. When he starts cooking fried chicken, he simply says “start cooking fried chicken”. Mr.Orange automatically consumes the required food, changes the food stock and sends the first step of the recipe. Afterwards, it sends the next step everytime receiving “next for fried chicken”. Our subject can simply check the instructions shown on Mr.Orange when he forgets which step he is currently at. Sometimes the recipe requires stand alone cooking for a period of time. In this case, Mr.Orange sets up a timer upon receiving a “start” command and sends a reminder when the timer finishes.

Demo: See Fig.4c, video link, link2.

7.4 Appearance

The user might feel bored facing the same robot appearance everyday. Here two holes are designed on top of the robot where some decorative components can be easily plug-in. He may also design some decorations on his will, such as some customized for special holidays like Chirsmas.

Demo: See Fig.2, image link, link2, link3.

7.5 Movements

Mr.Orange can offer help anywhere around the house. Ideally, after learning the home map, it may even navigate to the location of a specific item to remind the user. At night, it will stay at its hub for charging. In the morning, Mr.Orange wakes up his user in the bedroom and follows him to the bathroom to remind him to get shaved. Later, it shows a full to-do-list to our subject. As the first thing would be preparing breakfast, it heads to the kitchen together with the user and moves towards the refrigerator or some shelf when he forgets the location of certain ingredients. Later, Mr.Orange said that it should be the watering day for the tomato and cucumber. It leads its owner to fetch the necessary items at the storage room and heads to the yard. There, it again reminds our subject about the vegetables that should be watered and that should be picked for later cooking usage.

Demo: See video link, link2.

7.6 Heat sensing

A separate heat sensing module would be installed near the cooktop and the stove but linked with Mr.Orange. Sometimes the user is about to boil some water but he removes the pot without turning off the cooktop. After some time, the sensor monitoring the temperature in real-time detects this abnormal heating pattern and sends a warning to Mr.Orange through wifi or bluetooth. Mr.Orange then shouts, “danger, overheat” to the user and also sends his wife a message when necessary.

Demo: See video link.

7.7 Battery alert

It is common even for normal people to forget to charge the phone. Mr.Orange would show a battery level indicator on its screen and send a low-battery warning audio message when its battery is lower than threshold. Ideally, it can automatically navigate to a charging hub at night when the user goes to sleep and would not need more service, similar to a vacuum robot.

8. Feature-Benefit Case Statement

Voice assistant: The voice assistant is most beneficial to the user. It allows for easy control and interaction with the device. With the voice assistant, our robot can assist patients with various types of disabilities, especially ones with visual disabilities.

Reminder: The reminder function is specifically designed for our patient to help with his memory loss and remind him to do daily activities such as getting dressed or shaved. It also benefits the patient’s family, since the reminder allows the patient to have better selfcare, so the family can be less worried about the patient.

Smart Recipe: The smart recipe function is also beneficial to the patient since it allows the patient to cook. Cooking is a big hobby of the patient in this case and being able to cook will improve his mental health.

Appearance: The appearance of our robot resembles a pet-like robot. Which can also be customized by putting on different head parts. The patient and family can enjoy decorating the robot and form a connection with the robot.

Movements: Being able to move on different terrains also means our robot can adapt to different environments. The automatic navigation function prevents the robot from being damaged by the environment, which indirectly benefits the healthcare cost.

Heat sensing: The heat sensing function benefits the patient by keeping him safe from possible cooking accidents.

Battery alert: The battery alert benefits the user by providing easier maintenance. The users are able to charge on time with the low battery alarm, so that the patient can be assisted with our robot at all times.

9. Utility Case Statement

Many social robots currently on the market use voice recognition to interact with humans. Our design takes the same approach using voice for communication between the user and the robot. Research also shows that elders are less likely to use high technology and prefer to simply speak with the device. In our design process, we thought that letting the robot roam around the house autonomously would prevent the patient from forgetting about the robot. It is also shown that having a physical object like a robot has a more powerful effect than an app on rehabilitation. Users know that the robot is not a real person, but they are more willing to interact and spend time with a robot when compared to a screen[5].

Our robot's job other than fulfilling the patient's disability (loss of memory) is to reduce the loneliness of the patient. Since the patient will be at home alone during the day, it is important to have a companion. Research showed that loneliness is a serious health risk for the elderly. For many elderly people, it's important to follow treatments and a set of well-being habits to stay healthy. Loneliness and isolation have become serious risks for health. According to NASEM, social isolation is associated with a 50% increased risk of dementia and loneliness among heart failure patients, a nearly 4 times increased risk of death, a 68% increased risk of hospitalization, and a 57% increased risk of emergency room visit. Our device will provide companionship and therefore, improve on the user's disabilities.

10. Feasibility Case Statement

Movement (Remote control & Autonomous): *Instructables website* provides a couple of instructions and validations for controlling the servo motors with IR receiver[6]. The source code of Arduino IDE is well-documented and thus can be used as a feasible reference in our prototype.

Heat sensing: PTC thermistor has long been used to construct temperature sensors. The resistance of the thermistor decreases as temperature rises, which is usually due to an increase in conduction electrons bumped up by thermal agitation from the valence band[7]. Many circuit design projects in undergraduate courses use thermistor as their topic of physics experiment to verify its temperature sensing capability, in which Steinhart-Hart equation provides theoretical support[8].

Battery alert: Analog pins on the Arduino UNO board can receive input electrical signals from external voltage sources. Therefore, it is easy to measure the voltage across the battery.

Voice assistant: There are already a number of established voice assistants exemplified by Alexa. Existing social robots also realize communication efficiently through directly incorporating such established products. Temi, for instance, includes conversational assistance via Alexa.

Reminder: This function has been common across smart devices and should pose no technical issue to development of the device.

Smart Recipe: While basic smart recipe functions can already be realized through open-source APIs, the prototype hasn't touched on any video instructions. This part should also be feasible as certain educational platforms just like canvas would offer automatic plausible tutorial videos.

11. Conclusions

Overall, we have demonstrated that the design of the robot, Mr. Orange, fulfills the patient's requirements and is able to account for the benefit of the patient and his family. Additionally, the final prototype validated that our designed functions are feasible in technical terms and the demo showed that the utility of the robot accords with our imagination in the storyboard. Admittedly, the design process appears to be a little hasty, since we're given merely two weeks from the start of the design to finish the prototype. However, the completeness of the prototype exceeded our expectations. There are also many aspects to improve if given more time and hardware resources and many future indications are prospective to develop. For example, we could add a graphical user interface on the user's mobile device for better user-robot interaction. Plus, we can either use a better processing board other than Arduino UNO or embed a SD card

to improve the board’s memory storage, so that more functions can be incorporated in a smaller space, reducing the weight of the robot. For future prospects, features like patient fall detection is also considerate in case that the patient has a risk of falling. Smart home features with sensors embedded in the furniture at home could also expand the sensing capability of the robot, providing way better user experiences. It would also be great if the robot can allow a drop-in video chat with the patient's family, friends, and physicians, which provides more convenience to the patient.

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Appendix

I. Tables

Table 1. Gap analysis of existing social robots

Priority	Requirements	 ElliQ	 iPal	 Buddy	 Jibo	 Temi
2	Cost	$1,499	$3,499	$999	$899	$3,999
3	Easy Elder Use	+	+	+	+	+
3	Companion	+	+	+	+	+
2	Reminder	+	+	+	+	+
2	Mobility	-	+	+	-	+
1	Recipe	-	-	-	-	-
3	Battery Alert	+	+	+	+	+
3	Emergency Warning	+	+	+	+	+
2	Smart Home	+	+	+	+	+
3	Drop-in Video Call	+	+	+	-	+
3	Brain Exercises, Entertainment	+	+	+	+	+
4	Humanoid	-	+	+	-	-

Table 2. Parts list for prototype

Function	**Parts**
General	Elegoo UNO board x2, Breadboard (medium size) x1, 330 ohm resistors x2, 10k ohm resistors x4, Jumper wires, Acrylic casing, 3D printed PLA covering
Autonomous Movement	Servo motor x1, Ultrasonic module x1, Rubber wheels x2, Continuous servo motor x2
Smart Recipe	Grocy API, Spoonacular API
Voice Assistant	Bluetooth module HC-05 x1, Speaker x1, 16X2 LCD screen x1, HeyAthena, Python 3.10
Temperature Sensor	Thermistor x1
Remote Control	IR module x1

II. Figures

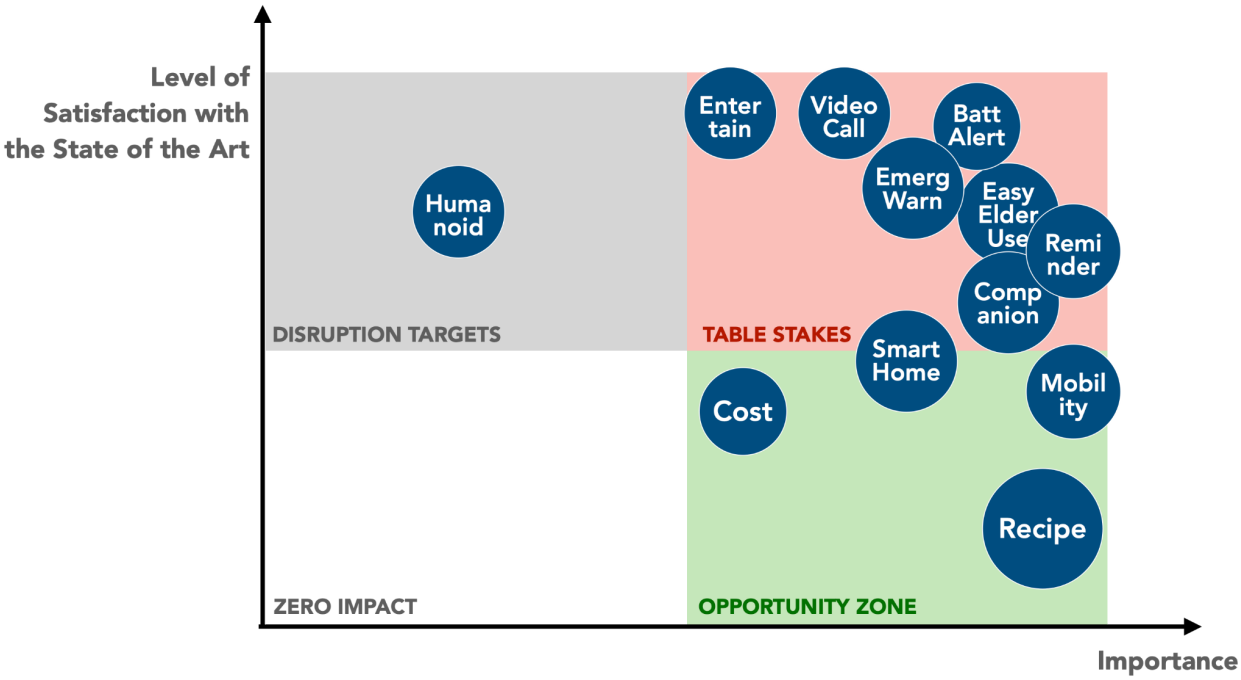


Fig.1 Importance-Satisfaction analysis. The horizontal axis indicates the importance of the feature, the vertical axis indicates the user satisfaction against the state of the art products. The high importance, low satisfaction region is the opportunity zone where features would be assigned with high priority; high importance, high satisfaction region is the table stakes zone where features should be provided but requires less design improvement; high satisfaction, low importance region is the disruption targets that should not be focused.

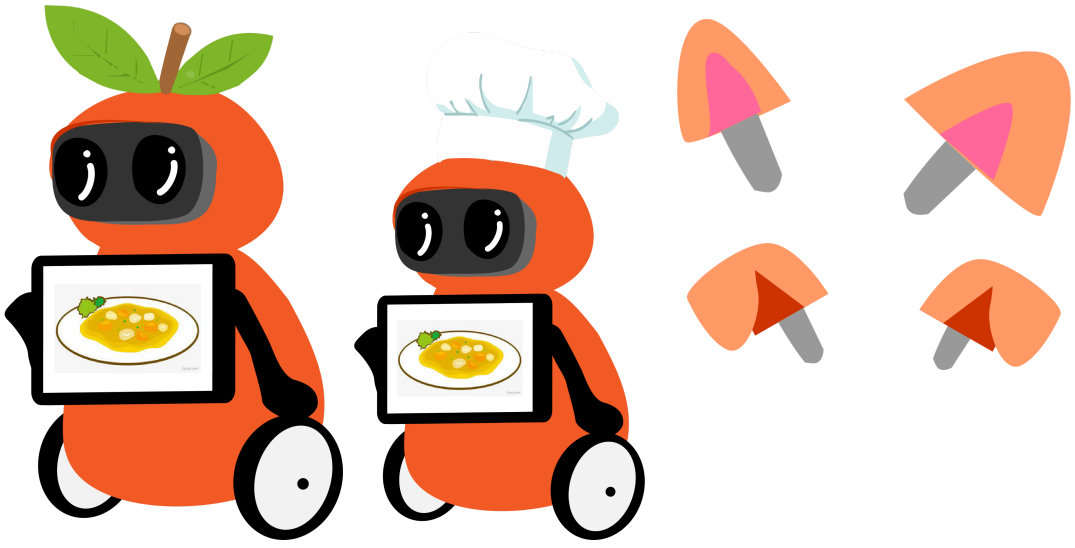
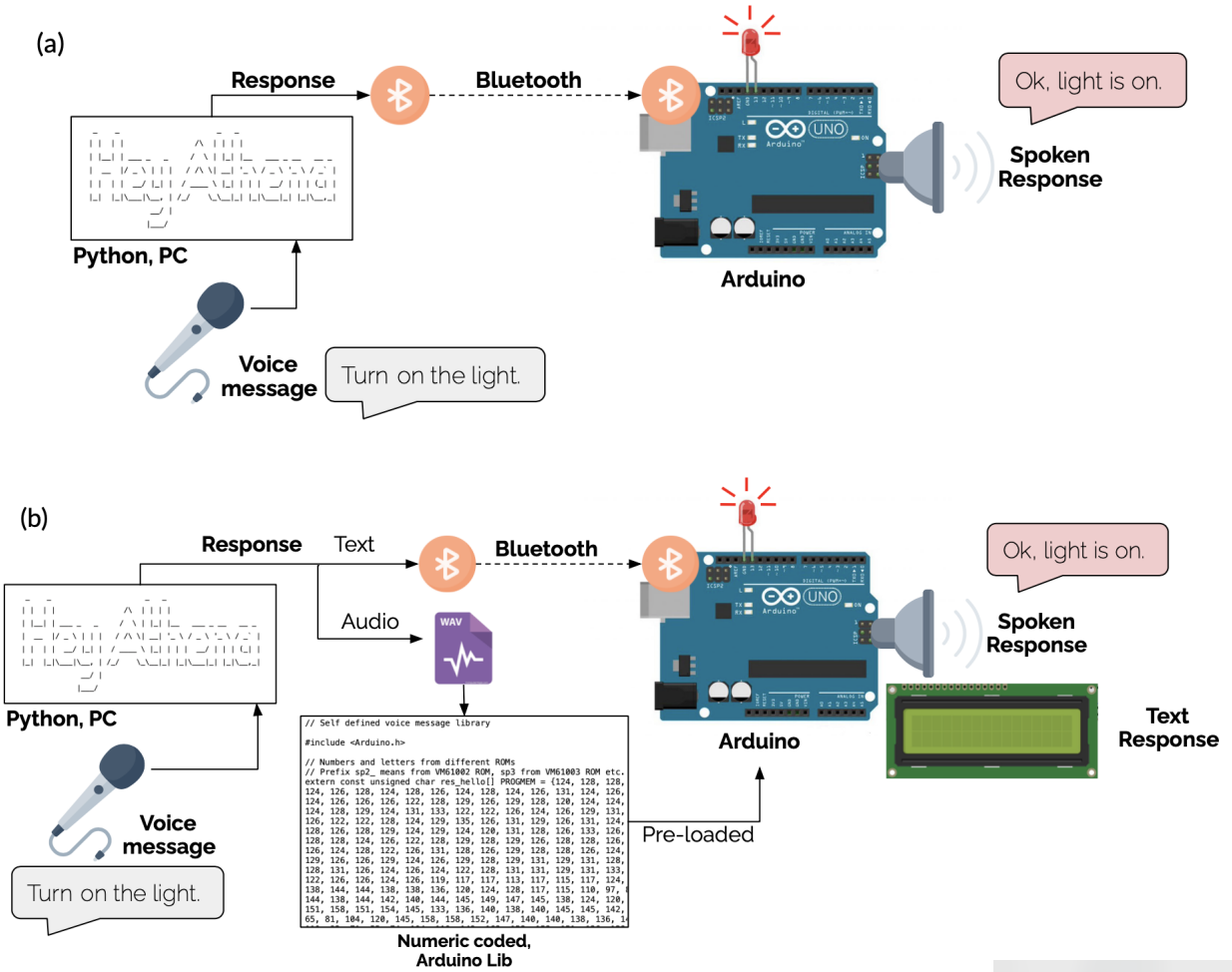


Fig.2 Final solution Mr.Orange. Left: Customizable appearance; Right: Plug-in decorations.


(a)
Response
Bluetooth
Ok, light is on.
Spoken Response
Python, PC
Arduino
Voice message
Turn on the light.
(b)
Response
Text
Bluetooth
Audio
WAV
Ok, light is on.
Spoken Response
Python, PC
Arduino
Text Response
Voice message
Turn on the light.
Pre-loaded
Numeric coded, Arduino Lib
(c)
1. Search: e.g. Recipe for Fried Chicken.
2. Start cooking now?
Start Now
(2.5. You have x items missing)
3.1 Step1
Next
3.2 Step2
(d)

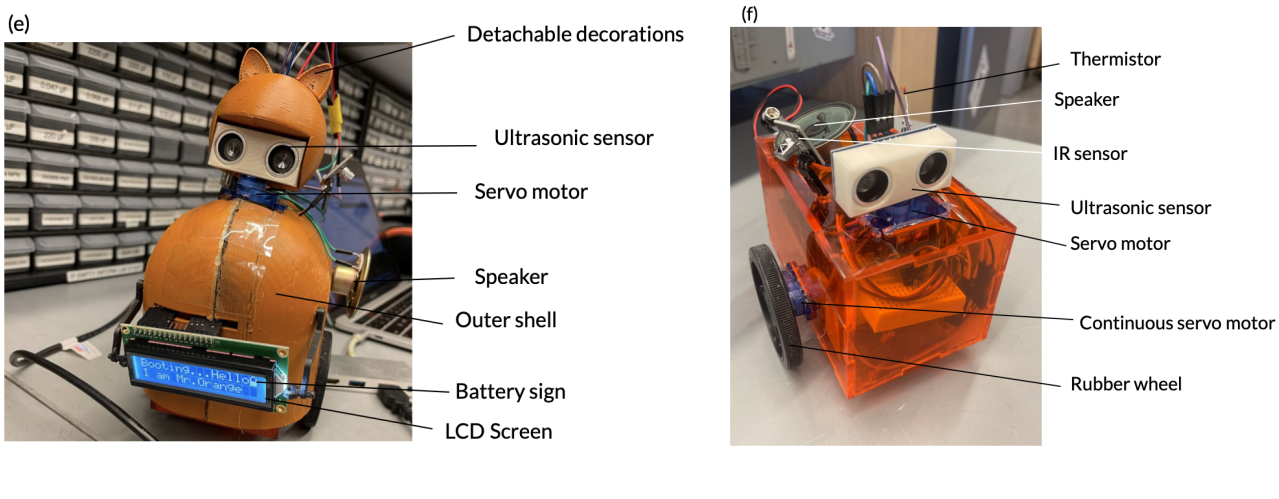


Fig.3 Prototype details. (a) Ideal workflow of voice related functions, (b) Actual workflow of voice related functions, (c) Realized recipe-related commands, including search, start, missing items, and interaction through next, (d) Models of outer shell and decorations, (e) Actual final prototype, (f) Intermediate prototype, (g) Inner organization.

For more details, please refer to this prototype demo document.

Mr. Orange video demo

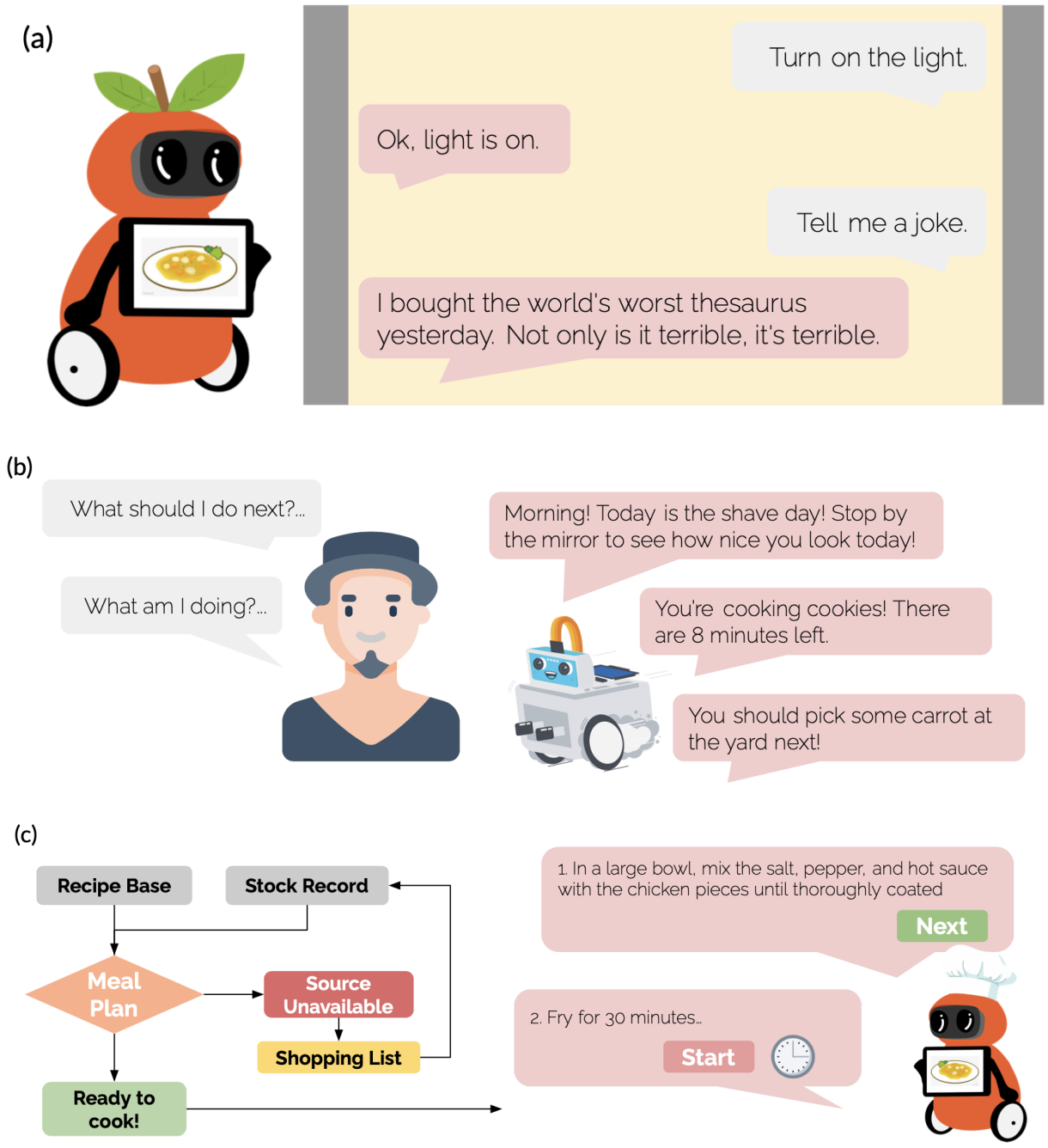


Fig.4 Storyboard illustration. (a) voice assistant, (b) reminder, (c) smart recipe.

III. Intermediate Design Options

a. Robot with carts

A movable robot with a detachable cart. As our subject may forget things easily, a cart may help carry some useful things with the user as the robot moves around, thus saving his effort in finding things around the house. He may also put some ready-to-use items in the cart which themselves perform as a reminder for the next-step tasks. For instance, he can use the robot to carry the vegetables needed for the meal and he would not forget about the dishes to cook once saw the vegetables remaining in the cart. This design applies the ***tolerance for error*** and ***low physical efforts*** design principles as it discourages putting stuff randomly somewhere and finding things around the house.

b. Desk robot with serving screen

A desk robot specialized for kitchen assistance and recipe interaction. It has a head showing human-like facial expressions and holds a display screen on its hands just like a serving plate. With graphical recipes shown on the screen, it is just like the robot is serving a dish. The expression and conversations of the robot would be customized as if he can actually smell and taste the dish to enhance interactions with the user. This design applies the ***identity meets ability*** tension to focus on the subject's love for cooking.

c. Robot with recipe preparation guidance

This robot is equipped with a projector that may project required ingredients on the kitchen worktop to instruct the user to check for resource availability before cooking. The user may bring all required items near according to projected instruction and put them back after use to keep track of progress. This design applies the ***tolerance for error*** principle as it discourages ingredient checking that requires vigilance and attention.

d. Housework and yarding companion

This robot is specialized to work as a housework and yarding companion. It is equipped with a water container and spray for watering and wetting and some detachable components meant for cleaning and farming like brushes and plows. Aside from normal reminders and movement function, it helps with cleaning and yarding. However, instead of performing as a tool, it works together with the user to offer companionship and features for human-like natural conversation. This design applies the ***identity meets ability*** principle to focus on the user's interests in

yarding and his main activity context at home.

e. Smart kitchen

This system possesses a highly organized, detailed record of all cooking appliances, ingredients and food stock. It not only keeps track of the quantity of foods and ingredients to remind the user about availability but also the location of the items in case the user fails to find them. Special camera monitors, scanners, pots, and containers are used in the kitchen. The scanner would pre-record an identity code of each equipment like spoons and bottles and automatically detect the trajectory of each during cooking so as to track if specific ingredients have been used. It can then remind the user of the cooking process when he gets lost. Similar mechanisms can be applied to other facilities and tools to help with housework. A movable humanoid would be used as embodiment of the system. It can turn the process of figuring out the following tasks into a brain exercise - the user may make a guess whereas the robot gives the correct answer through conversations. This design applies the ***identity meets ability*** design tension by focusing on his interests in cooking and the ***simple and intuitive use*** as it fits perfectly into the normal working process.

f. Robot with caterpillar track and customizable decoration

This robot uses a caterpillar track to enable smooth movement throughout the house and the yard. It is designed to be of simple appearance but with decorative parts the user can design and change freely. This design applies the ***identity meets ability*** design tension to encourage the user to pursue his loved appearance.

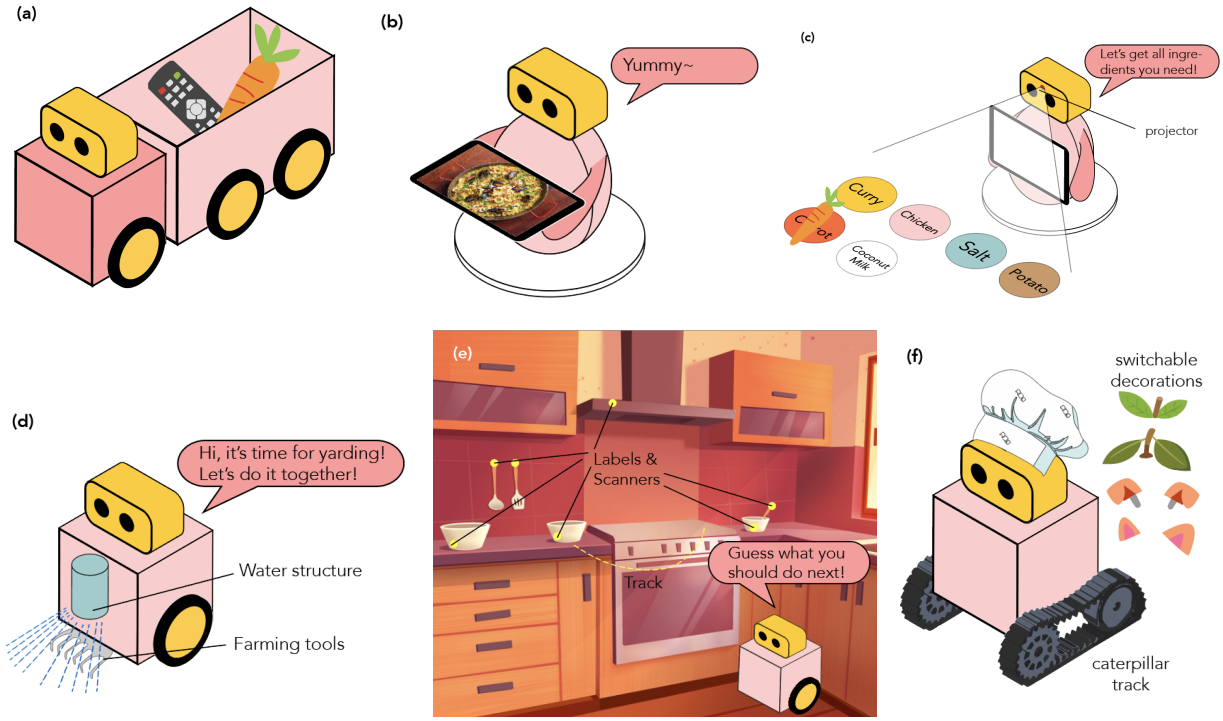


Fig.5. Sketches of intermediate designs.